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(71) Applicant
Lucas Industries Public Limited Company
(Incorporated in United Kingdom),
Great King Street, Birmingham B19 2XF

(72) Inventor
Domingo Cabarrocas Pruneda

(74) Agent and/or Address for Service
Marks & Clerk, Alpha Tower, Suffolk Street
Queensway, Birmingham B1 1TT

(54) Electromagnetic actuators for controlling injection pumps

(57) An electromagnetic actuator for controlling an injection pump includes a core member 7 and an armature 12 slidable towards and away from the core member. The presented faces of the armature and core member are of frusto conical form and the exterior surface of the armature is of tapering form. A winding 4 surrounds the core member and armature and is mounted within a tubular body 2 which at one end is magnetically coupled to the core member. The actuator may move a component forming part of the fuel supply system of an internal combustion engine.

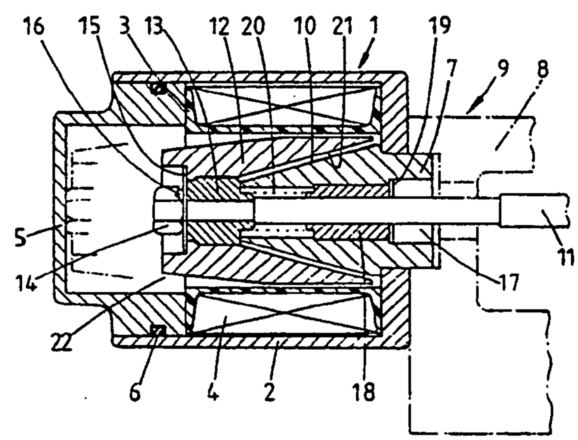

FIG. 1.

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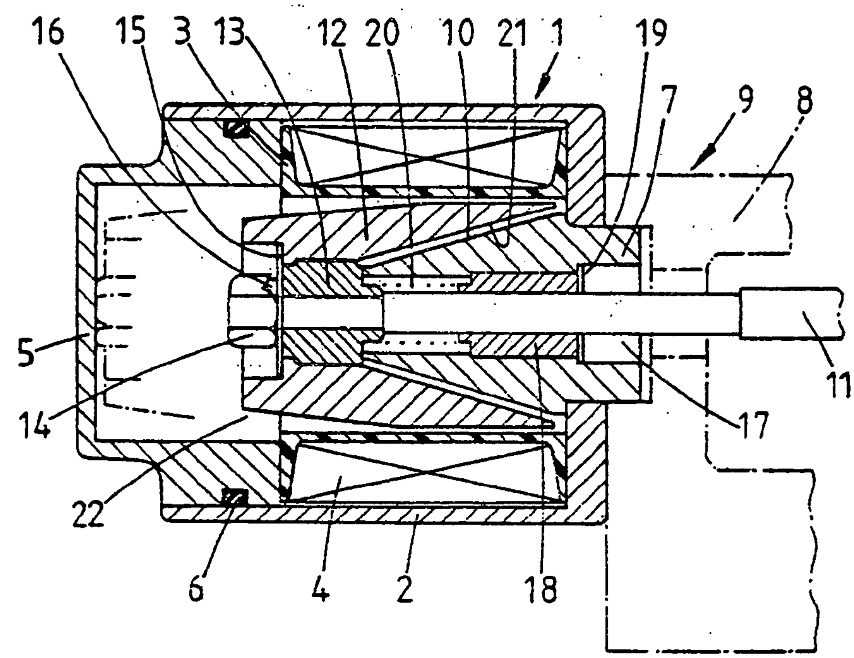

FIG.1.

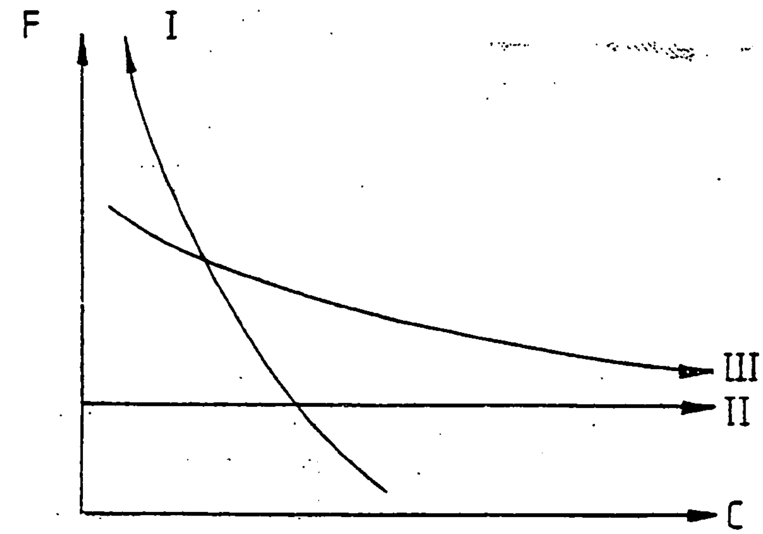

FIG.2.

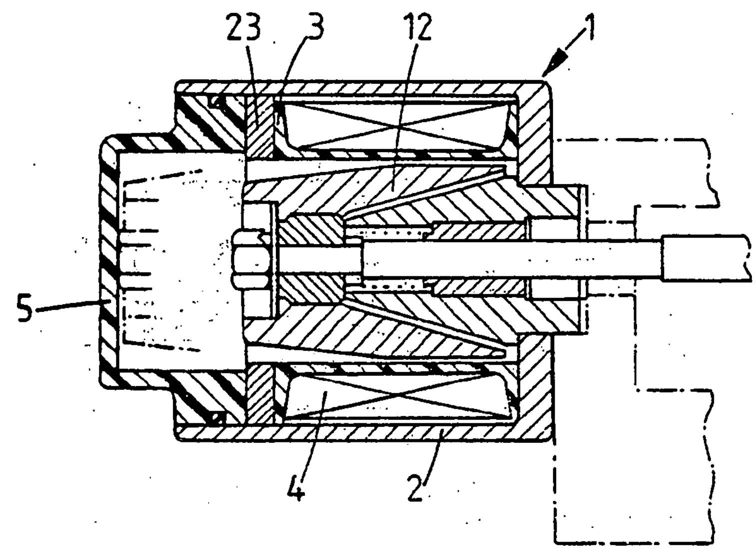

FIG.3.

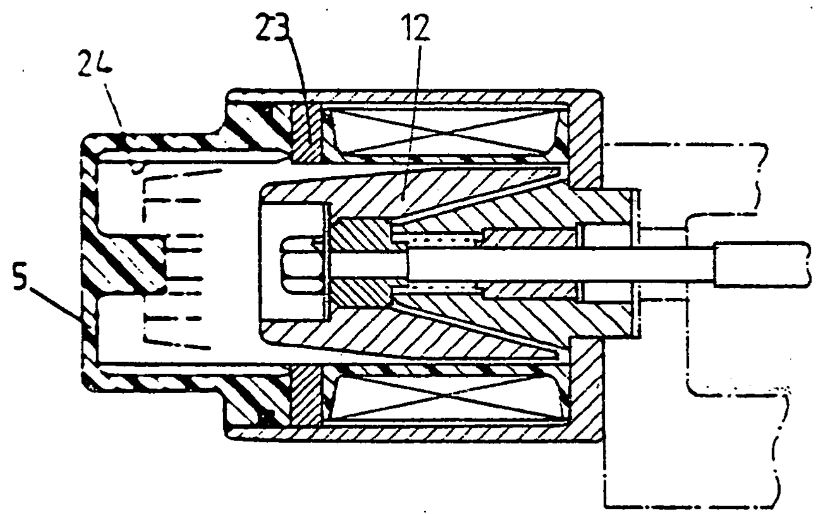

FIG.4.

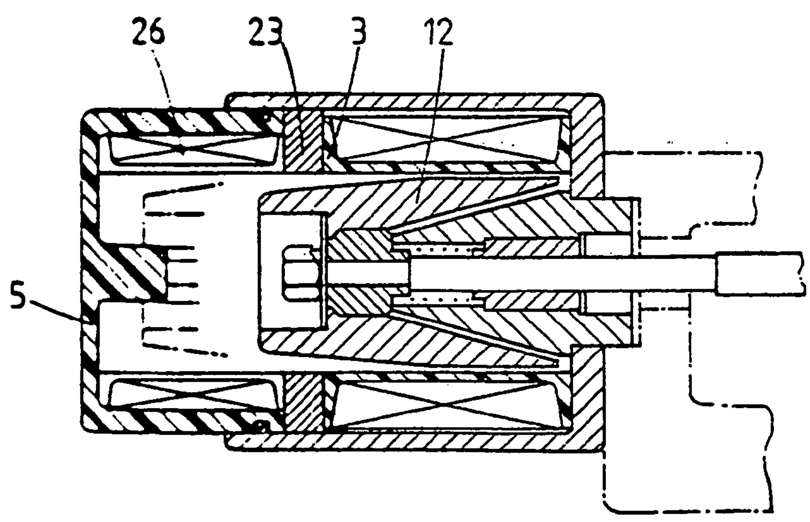

FIG.5.

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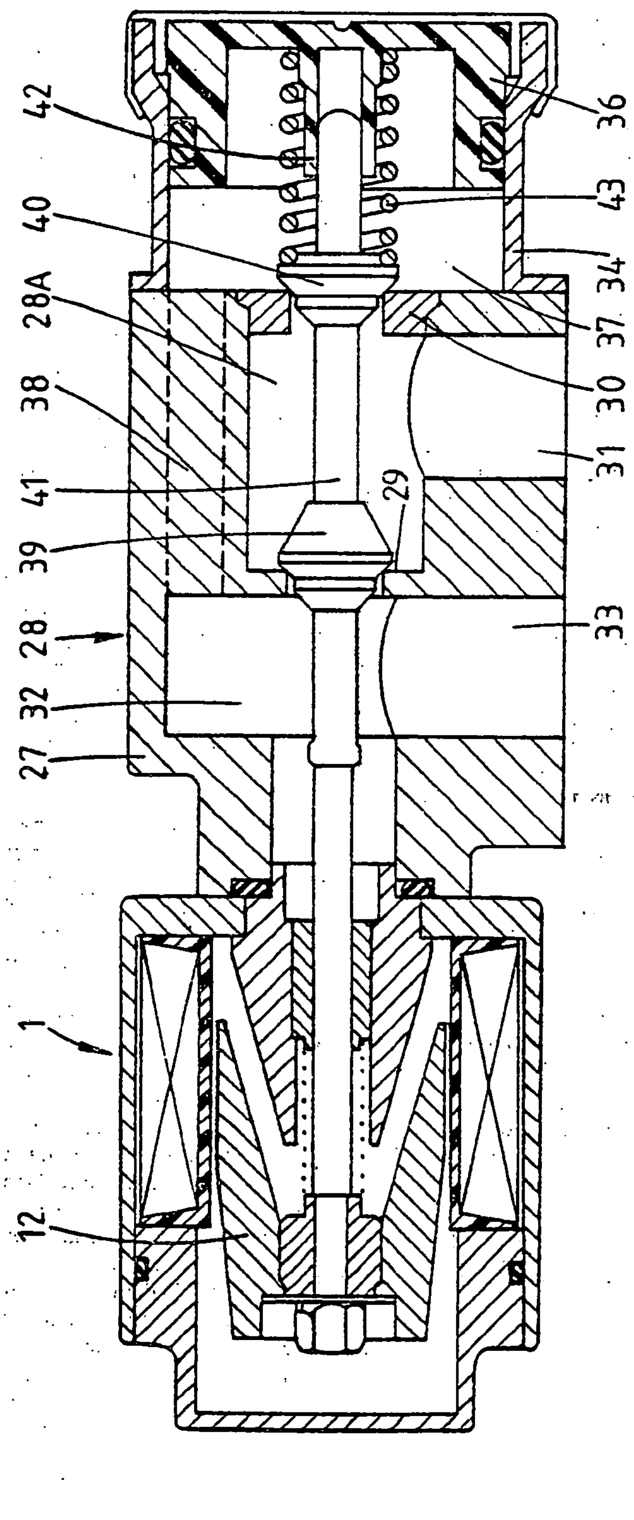

FIG.6.

SPECIFICATION

Impr vements to el ctromagnetic actuat rs for controlling injection pumps

This invention relates to electromagnetic actuators more particularly but not exclusively to actuators for effecting movement of a component forming part of the fuel supply system of an internal combustion engine.

In one application of the actuator, the actuator is used to vary the setting of a fuel quantity control rod of a fuel injection pump of a compression ignition engine. In another application the actuator is used to control the setting of a valve which forms part of the overall fuel supply system of a fuel injected spark ignition engine the valve being connected in parallel wiht the normal air throttle valve.

Various types of electromagnetic actuators are known. Generally, electromagnetic actuators provide an actuating force when current is passed through a winding, the force causing an element of the actuator to be displaced to a limiting stop, the element returning to its initial position under the action of a spring once the current flow through the winding is interrupted. The magnetic field is modified by the displacement of the element of armature and the alteration in the magnetic circuit causes a substantial variation in the electromagnetic force for a short travel of the armature. In view of the fact that, in order to move the moving armature, the electromagnetic force must overcome the opposition of the restoring spring, electromagnetic actuators possessing these features have only two stable positions available for the moving armature.

With a view to avoiding substantial modification of the magnetic circuit during displacement of the armature, and thereby obtaining a virtually constant actuating force, electromagnetic actuators exist whose winding and armature have a length which is much greater than the diameter of the same. However, the electromagnetic force which can be obtained using these dimensions is small, and inadequate for certain actuation tasks.

The object of the invention is to provide an electromagnetic actuator in a simple and convenient form.

According to the invention an electromagnetic actuator comprises a hollow body defining an elongated chamber, a core member extending into said chamber, said core member having a truncated conical surface within the chamber, an aramture slidable within the chamber, the end surface of the armature which is presented to the core member having a shape complementary to that of the core member, said core member and the body forming part of a magnetic circuit which includes also the armature and the air gap between the armature and the core member and the air gap between the armature and the body, and the side surface of the armature at least over the end portion thereof remote from the core member being of tapering form, a winding which when energised induces magnetic flux flow in said magnetic circuit and resilient means f r opposing mov ment of the armature towards said core member under the action of the magnetic flux.

The device forming the subject of the pr sent invention was conceived with a view to improving the force/travel characteristic, and moreover obtaining further advantages which will be apparent to those skilled in the art, the said device being fundamentally characterized in that the fixed armature is provided on one of its sides with a frustoconical form, in that the moving armature possesses on its larger base a frustoconical cavity which complements the said side of the fixed armature on which the moving armature comes to rest after its displacement, and in that the said moving armature is designed as a body of revolution having a concavely curved generatrix varying with its displacement the distance between a point on the coil and the said moving armature, in order, by means of this arrangement, to enable the electromagnetic force to be balanced, at any point on the travel of the moving armature between the positions remote from and nearest to the fixed armature, with the force of the opposing spring and the moving armature to be positioned at any point on the said travel.

In the accompanying drawings:—

Figure 1 is a sectional side elevation of an electromagnetic actuator according to the invention,

Figure 2 is a force/travel graph in which the characteristic curves of various electromagnetic actuators are shown, and

Figures 3, 4 and 5 are sectional side elevations showing modifications to the actuator of Figure 1.

For greater ease of description of the examples, the component parts of the actuator having the same function retain the same reference numerals in the different figures.

The electromagnetic actuator 1 in Figure 1 comprises a cup-shaped body 2 formed from magnetic material within which is mounted a plastics or like insulating coil former 3 which supports a winding 4 of copper wire. A hollow cap 5 formed from magnetic material closes the open end of the body 2 and may be secured using a screw thread. The cap locates within the body and engages the coil former 3 and urges the former against the base wall of the body 2 and this portion of the cap within the body is of substantial thickness. A gasket 6 provides for sealing between the cap and body and a magnetic core member 7 is fitted into an aperture in the base of the body 2 and has a spigot which is utilized to secure the body 2 to the body 8 of an injection pump 9. The core member 7, on its side remote from the injection pump 9 is of frustoconical form at its surface 10.

The armatur 12 of the actuator is mount d on one end of the control rod 11 of the injecti n pump 9 by m ans of a bush 13 of non-magnetic mat rial, which is a press fit in the armature 12. The end of th control rod 11 is provided with a screw thread to receive a non-magnetic locking nut 14 which urges the bush against a shoulder on the control rod. A washer 15 is located beneath the nut which is also provided with a locking washer 16. Th nut is partly recessed within the armature.

The cor member 7 has a c ntral ap rtur 17

which mounts a bush 18 of a wear resistant material such as bronze and the bush is retained in position by means of a circlip. This support of the control rod 11 makes it possible to dispense with a support on the injection pump, and in this manner permits a more compact design thereof.

Between the core member 7 and the armature 12, or more accurately between the bushes 18 and 13 incorporated therein is a helical compression spring 20, which opposes the movement of the armature towards the core member. By arranging the spring 20 around the control rod 11, maximum use is made of the available space within the electromagnetic actuator 1, thus reducing the constructional cost thereof.

The magnetic flux created by the passage of electric current through the winding 4 flows through the armature 12, the core member 7, the body 2, the cap 5 and the air gaps included between said components.

The electromagnetic force caused thereby urges the armature 12 from the position indicated in broken lines in Figure 1 in which the armature is spaced from the cap by the projecting portion of the nut, to the position shown in continuous lines. The armature 12 on the pump side is provided with a cavity having a frustoconical surface 21, complementary to the surface 10 of the core member 7. The cone angle of this surface plays a decisive part in influencing the behaviour of the actuator 1, in that a larger cone angle provides greater efficiency for less travel. By selecting the greatest cone angle compatible with the travel required for the control rod 11, a curve I is obtained, as is shown in Figure 2, where it may be seen that the force achieves a high level when the armature and core member are close, the travel being very short, the force diminishing sharply as the armature separates from the core member.

The curve I therefore corresponds to electromagnetic actuators as earlier described having two stable positions. Similarly, actuators of small diameter relative to their length present a characteristic curve as shown at II in Figure 2, that is to say they provide a virtually constant electromagnetic force during the displacement of the armature. This force is too small for the operation of the control rod 11 of an injection pump.

The armature 12 of the actuator 1 according to the invention is designated as a body of revolution, having a concavely curved generatrix, and its lateral surface 22 is so designed that the separation between the said surface and the cap varies with the displacement of the moving rmature 12. In this manner, a profile of the lateral surface 22 can be designat d so as t btain a curve III which is flatter than the curve I corresponding to a cylindrical lateral surface. The variation in th electromagnetic force is thus moderated, and by selecting appropriate dimensions for the opposing spring 20 it is possible to balance the spring and magnetic f rces and to position the moving armatur 12, and hence the control rod 11, in a stabl manner at any point in the travel of the moving armature 12 between the positions most remote fr m and nearest to the core member 7.

The electromagnetic actuator 1 shown in Figure 3 is provided with a cap 5 of non-magnetic material such as plastics and a ring 23 of ferromagnetic material is provided and is located between the cap 5 and the coil former 3 in contact with the internal surface of the body. With this arrangement, the magnetic flux is virtually confined within the ring 23 which leaves the internal surfaces of the cap 5 and any space between the surface and the armature free. In Figure 4, the inner surface of the cap is fitted with a capacitive type sensor 24 the capacitance of which varies depending upon the position of the armature. In the arrangement of Figure 5 and cap 5 carries an inductive type sensor 26. The signals provided by the sensors can be fed back to a control unit, which is not described, but which acts to control the current flow in the winding 4 to move the control rod 11 and vary the operating state of the engine. It will be noted that in the examples of Figures 4 and 5 the cap defines a stop for engagement by the nut which is recessed within the armature.

In the arrangement shown in Figure 6 the actuator 1 as shown in Figure 1 is secured to the main body portion 27 of an air control valve generally designated 28. The valve 28 is connected in use in parallel with a manually operable air throttle valve of a fuel injected spark ignition engine, the valve providing for a controlled bleed of air under certain engine operating conditions.

The main body 27 of the valve defines a valve chamber 28A at the opposite ends of which are disposed annular seatings 29, 30 and the chamber communicates with an outlet 31. The body 27 also defines an inlet chamber 32 which is disposed on the side of the seating 29 remote from the chamber 28A and the inlet chamber communicates with an inlet 33. Secured to the end of the main body 27 remote from the actuator is a hollow extension 34 having its open end closed by a cap 36 which is retained in position by a cup-shaped retainer member. The extension and cap define a balancing chamber 37 which is in communication with the inlet chamber 32 by way of an axial passage or passages 38 defined in the main body.

Located in the chambers 28A and 37 are valve members 39, 40 respectively the valve members being carried on a stem 41 which at one end is slidably supported in a tubular spigot 42 integral with the cap 36. At its other end the stem is connected to the armature 12 of the actuator 1 in the same manner as the control rod. The valve members 39, 40 define conical surfaces presented to the seatings and the seat areas of the valve members and their seats are substantially equal so that in the closed position of the valve which is attained by means of a coiled compression spring 43 locat d between the valve member 40 and the cap 36, th valve memb rs and stem are substantially pressure balanced. As th winding of the actuator 1 is energised the valve members will move against the action f the spring 43 and the spring in the actuator, towards the fully open position with air from th inlet chamber flow directly

into the valve chamber 28A and indirectly by way of the passage or passages 38 and the balancing chamber.

CLAIMS

1. An electromagnetic actuator more particularly but not exclusively for use in an engine fuel supply system the actuator comprising a hollow body defining an elongated chamber, a core member extending into said chamber, said core member having a truncated conical surface within the chamber, an armature slidable within the chamber, the end surface of the armature which is presented to the core member having a shape complementary to that of the end surface of the core member, said core member and the body forming part of a magnetic circuit which includes also the armature and the air gap between the armature and the core member and the air gap between the armature and the body, and the side surface thereof remote from the core member being of tapering form, a winding which when energised induces magnetic flux flow in said magnetic circuit and resilient means for opposing movement of the armature towards said core member under the action of the magnetic flux.

2. An actuator according to Claim 1 including an actuating rod connected to the armature and a bush mounted within an aperture in the core member said bush acting to support said rod and said armature for axial movement.

3. An actuator according to Claim 2 in which said rod is secured to the armature by way of a sleeve formed from non-magnetic material which is secured within the armature.

4. An actuator according to Claim 2 in which the resilient means is in the form of a helical spring which surrounds said rod.

5. An actuator according to claim 1 in which said body is of cup-shaped form with the core member having a spigot which projects through an aperture in the base wall of the body.

6. An actuator according to Claim 5 in which said spigot is utilized to secure the actuator to a body forming part of a device to be actuated.

7. An actuator according to Claim 1 including a cap formed from magnetic material and which serves to close the end of the body remote from the core member.

8. An actuator according to Claim 1 including a ring formed from magnetic material said ring being mounted within the body at a position remote from the core member, said ring forming part of the magnetic circuit between the body and the armature.

9. A fuel injection pump for supplying fuel to an internal combustion engine including an actuator as claimed in any one of the preceding claims.

10. A fluid control valve for use in an engine fuel system including an actuator as claimed in any one of Claims 1—9.

11. An electromagnetic actuator for use in an engine fuel system substantially as hereinbefore described with reference to the accompanying drawings.

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